INTERFERENCE PERFORMANCE REPORT

Date: September 12, 1990

Author: Behruz Rezvani

The interference tests have been done for both base station and transporter receiver. The tests consist of BERT (bit error rate test) in band channel interference, 6.25 KHZ adjacent channel interference, 25 KHZ adjacent channel interference and image channel interference tests. From these, BERT and 6.25 KHZ adjacent channel tests are in separate reports which were provided earlier. However, a copy will be enclosed in this report. The remaining reports are included in he following paragraphs.

The setup in Fig. 1 is used to measure the effect of interference to the base station receiver. Although the interference signals varies from on test to another, the test setup is the same throughout the test.

- (a) In the setup of Fig 1, the first HP attenuator (VA1) is set at 50 dB and the second attenuator (VA2) is set at 5 dB. The power at frequency of 928.5375 (MHZ) is -68 dBm measured at the spectrum analyzer port which means the incident power at the input coupler is -48 dBm. Therefore, the received signal at receiver of base station is -108 dBm. In order to receive an interference at the receiver with the same level (-108 dBm) the signal generator for the interference signal power level should be set at -28 dBm.
- (b) In Fig. 6 is used to send interference to the remote unit receiver and record the results. Again in this case, one setup is used for the whole interference test.

IN BAND INTERFERENCE TEST.

In order to simulate the signal with the same spectrum as the remote unit transmitter, the signal generator modulated with 725 Hz square wave at 3 KHZ deviation rate. The spectrum is shown in Fig. 2 and 3. The result of the measurement for in band interference is in Table 1.

f = OKHZ

S/I [dB]	Total bit count	Bit error	BER
30	20112	12	5.9×10^{-4}
25	20160	12	5.9x10 ₋₄
20	20112	19	9.4x10 ⁻⁴
15	20208	21	1.04x10 ₋₃
10			

The interference which was applied to the base station receiver, is a carrier with 2 KHZ squareware external plus. KHZ sinusoidal wave internal FM modulation at 2KHz deviation.

These waves from exhibits in the spectrum as shown in Fig. 4.

The results are tabulated below:

f=25 KHz

S/I [dB]	Total bit count	Bit error	BER
0	20160	9	4.5×10^{-4}
-10	20112	11	5.5x10 ₋₄
-15	20112	22	1.1x10 ⁻³
-20	20064	51	2.5x10 ₋₃

Table 2. 25 KHz Adjacent Channel

Interference

Image channel interference test.

In this case the same modulation as the one for 25 KHz interference test is used. The result is shown in Table 3.

f=42.8 MHz

S/I [dB]	Total bit count	Bit error	BER
0	20160	16	7.9×10^{-4}
-3.0	20208	80	3.9x10 ₋₃
-35	20064	323	1.6x10 ⁻²

Table 3 Image Channel Interference

The graph of BER vs. S/l is shown in Fig. 5 for all three cases.

In the setup of Fig. 6, the first Hp attenuator (VA1) is set at 5 dB. The power measured at the spectrum analyzer port at 952.5375 MHz is -55 dBm. As a result the incident power at the input of coupler is -35 dBm. Therefore, the received signal at the receiver of transponder unit is -90 dBm. In order to apply the same level of interference (-90 dBm) to the receiver of the transponder unit, the signal generator power level should be set at -15 dBm.

In Band interference test.

In order to simulate the signal with the same spectrum as the base station transmitter, the signal generator modulated with 725 Hz square wave at 3 KHz deviation rate. The spectrum is the same to the one in Fig. 3. The result of measurement is shown in Table 4.

f=OKHz

S/I [dB]	Total Counts	Bit Error	BER
+20	34224	3	8.7x10 ₋₅
+15	21408	5	2.3x10 ⁻⁴
+10	20256	7	3.4x10 ₋₄
+5	20256	132	6.5x10 ⁻³
+3	20208	626	3x10_2

Table 4 Transponder Inband Interference Performance Test Result.

25 KHz Adjacent Channel Test.

The interference used in this case is the same one with the spectrum in Fig. 4.

The results are illustrated in Table 5.

f=25KHz

S/I [dB]	Total Counts	Bit Error	BER
+20	34224	3	8.7x10 ⁻⁵
+15	21408	5	2.3x10 ₋₄
+10	20256	7	3.4x10 ⁻⁴
+5	20256	132	6.5x10-3
+3	20208	626	3x10_2

Table 4 Transponder Inband Interference Performance Test Result.
25 KHz Adjacent Channel Test.

The interference used in this case is the same one with the spectrum in Fig. 4.

The results are illustrated in Table 5.

f=25 KHz

S/I [dB]	Total Counts	Bit Error	BER
-0	20640	6	2.9x10 ⁻⁴
-10	22464	5	2.2x10 ₋₄
-20	20256	1	4.9x10 ⁻⁵
-25	23856	2	8.3x10 ₋₂
-30	20648	436	2.1x10 ⁻²

Image Channel Interference Test.

The interference signal spectrum in this test is the source as the one shown in Fig. 4.

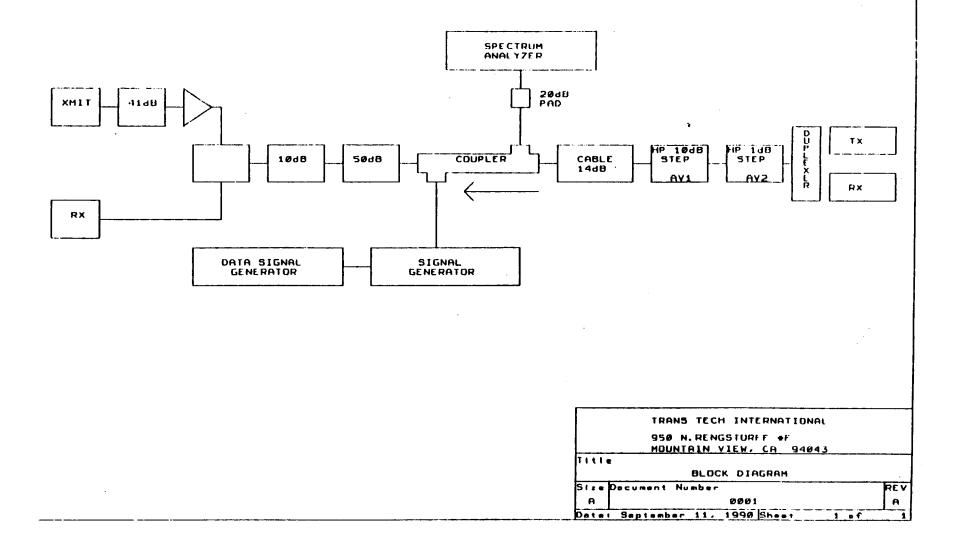
The result is shown in Table 6.

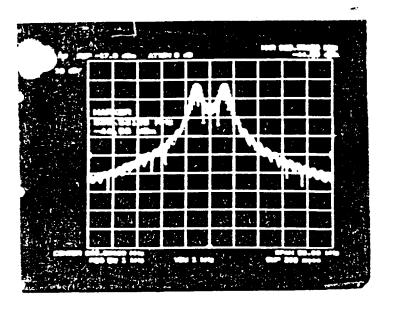
f=48.005 MHz

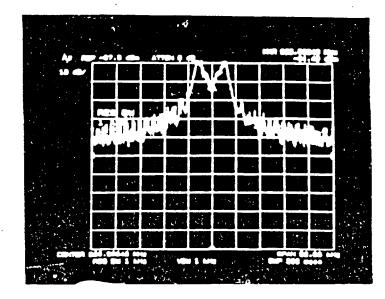
S/I [dB]	Total Bit Count	Bit Error	BER
20	20160	6	2.9x10 ₋₄
0	21552	5	2.3x10 ⁻⁴
-10	20688	7	3.3x10 ₋₄
-15	20256	5	2.4x10 ⁻⁴
-20	20304	0	0
-30	21024	3	1.4x10_4
-35	20208	420	2x10 ⁻²

Table 6 Image Channel Interference Test Results.

The graph of BER vs. S/I is illustrated in Fig. 7 for all three cases.



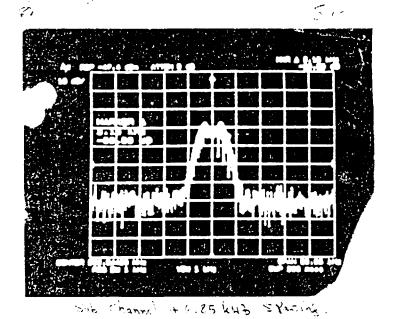




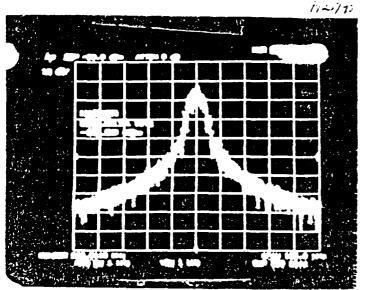
7/25/40

2

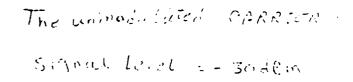
Free State OF KMIT STYPOL



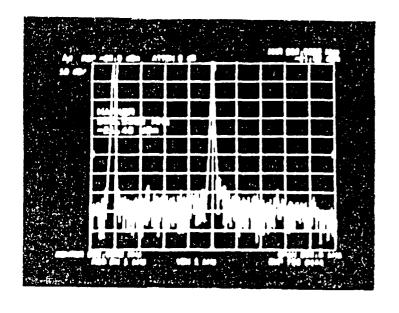
KEINDIZ KADIS SCLIPIED BANGNIDIN



TATELERONS



25 KHZ Brendwith at -36 ARM
Con interfer Sinnal (Moduleties
with IKHZ internal and
ZKHZ External with ZKHZ
deviction

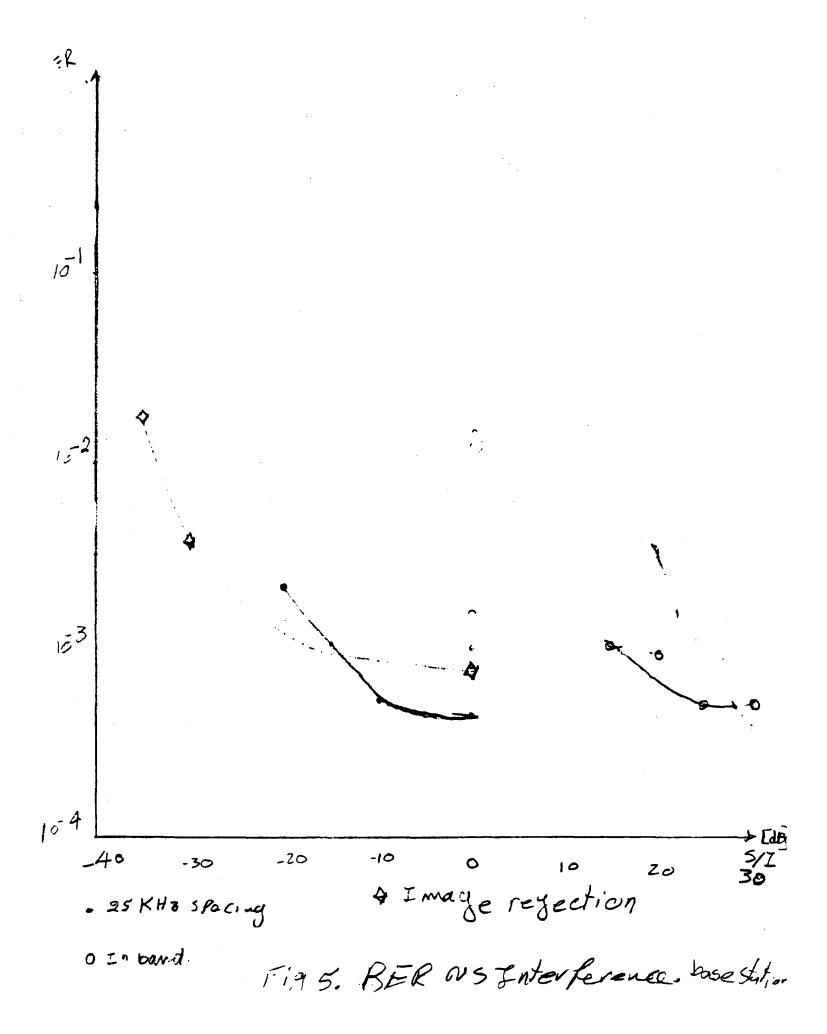


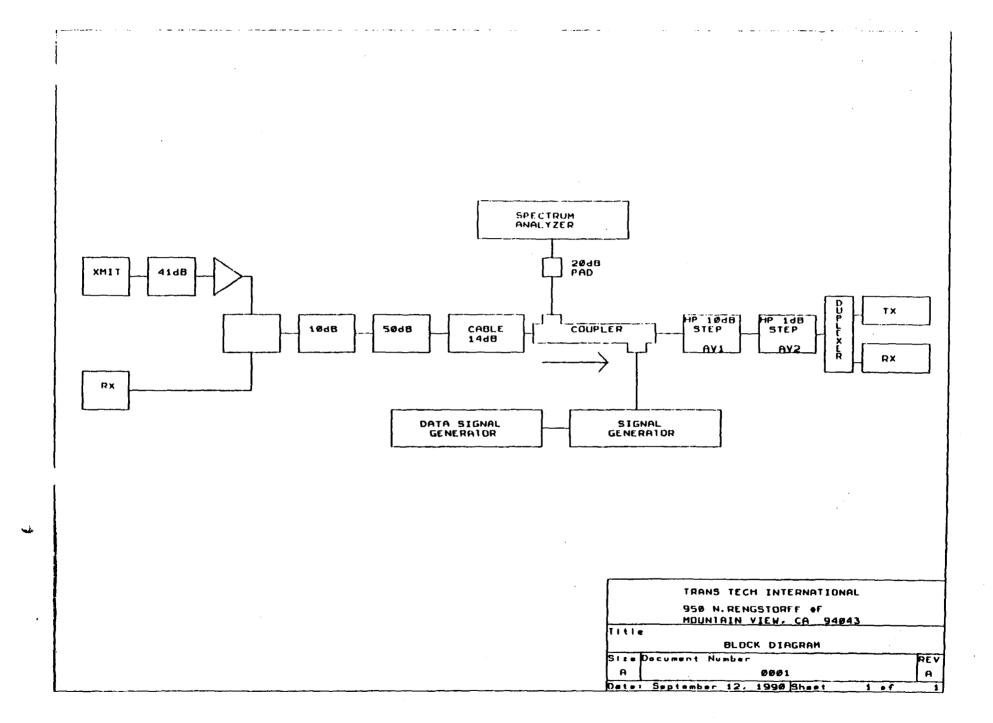
INTERFERANCE SIGNAL [-2dem)

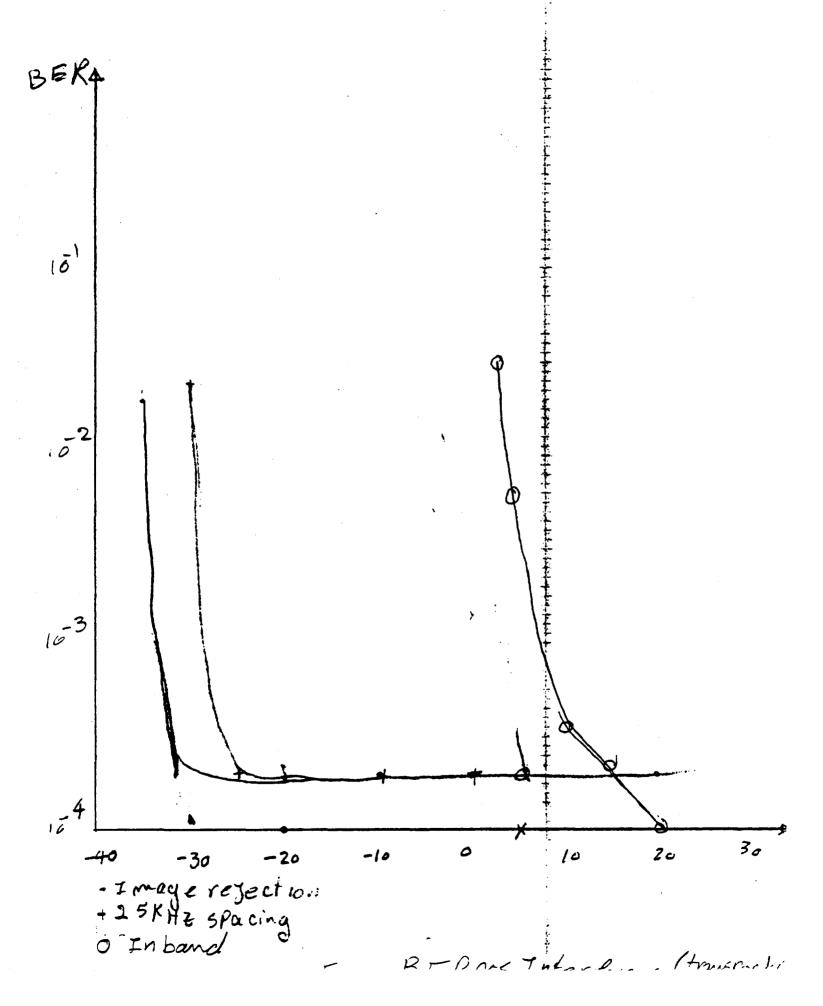
Fred = 952.4775

But Spectrum Analyze

IS OH 1.3 KHZ.









PROPAGATION EXPECTATIONS

Date: April 19, 1990 Author: Bruce Lusignan

Report#: 900419-24

Following are comments on results from the initial field test runs presented in the meeting of April 12, 1990. I am enclosing notes from my course at Stanford, EE 244B, on propagation predictions (Appendix A). I've enclosed both microwave relay applications and mobile radio applications for completeness. The mobile radio is relevant to the DAC application for most uses.

The graph on page 172, "Fig. 8. Field Strength Variations from 0.03 mi to 10 mi," covers the tests that were done.

The profiles for the test sites need to be run to determine the actual tower height above mean terrain. Note that the family of curves are for different tower heights, 100', 200', 500', 1000', 2000' and 5000'. To get the best prediction, a radial from the base station to each test site should be run and the average elevation calculated. Then the prediction can be read off of the chart

Some things to note:

- At 1 mile range with the transmitter 100' higher than the average terrain, the received signal is expected to be 14 dB below the free space value.
- If the tower height were raised to 1000' from 100', the range would be increased from 1 mile to 3 miles. The effect of tower height is very important.

To give an idea of the "expected" vs. the "measured" signal strengths, I have assumed all the sites you measured correspond to a 100' tower height above mean sea level. Figure 1 shows the "expected" reduction below free space loss as measured by the chart of page 172

Before we do the actual terrain profiles, it is simple to do some quick checks. Using the site map of San Rafael and the list of Figure 1, we can group the sites into those that are in the Same Valley with the transmit tower, those that are at the same level but nave an Intervening Mountain, and those that are at a distance but On a Mountain. Below I've done that grouping. The column "Variation" is equal to your "Act Vs. Est" minus "Est Free Space minus FCC Est". This gives the difference between the measurement and the FCC estimate.

Same Valley:	Site	Dist. (mi.)	Variation (dB)
	21	24.	10.0
	10	. 24	-10.0
		.34	-16.3
	22	.08	-8.8
	11	•58	-25.1
	15	• 68	-22.2
•	17	.68	-13.2
	18	1.02	-5.7
	19	1.00	-9.9
	16	1.38	-17.6
	7	1.66	+5.5
	5	2.07	-9.4
	12	1.89	-18.4
	13	1.98	-20.0
	14	1.98	-24.0
_Intervening Mountain:	: Site	Dist. (mi.)	Variation (dB)
	4 · 2 6	1.68	too low to measure
•	2	3.02	-19.3
		3.07	-18.7
	20	1.75	too low to measure
•	8	3.81	-15.3
	3	2.68	-18.8
	·		
On A Mountain:	Site	Dist. (mi.)	Variation (dB)
	1	5.03	-4.4
	1 9	1.68	-9.4
		•	

These results are approximately what was expected. The sites in the Same Valley show variation from +5 to -25 dB relative to the FCC projection. The variation probably is related to nearby structures which would show up in the site photographs.

The sites on the other side of an Intervening Mountain vary from 15.3 dB below the expected value to too low to measure (these are at least 30 dB below projections). The mountains cause about a 20 dB extra drop from the first case.

Where the sites are On a Mountain, the signal is much closer to the expected value, -4.4 to -9.4. This is true even at the range of 5 miles.

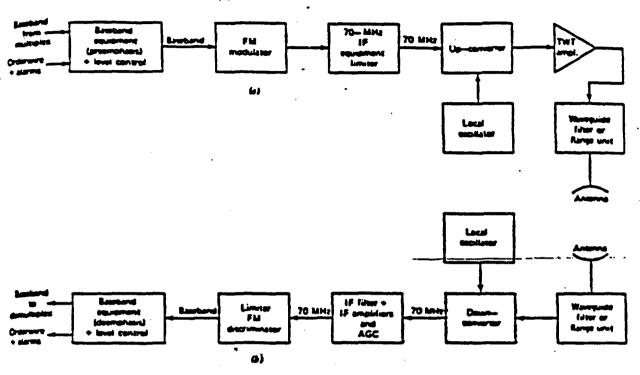
Once we get the profiles we will repeat these analyses. However, the above analyses show that we obtain mainly what is expected.

FIGURE 1: Phase I - Signal Strength Data

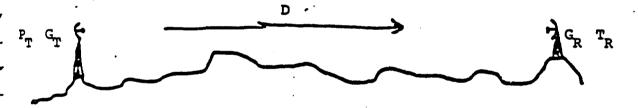
No.	Name Transmit Power (dBm) 42	Dist. (miles)	Elev. (feet)	Rise (Fall)	Bearing (°)	Rcv. Signal (uncorr) (dBm)	Path Loss (dB)	Rcv. Pwr Est. (dBm)	Rcv. Pwr Actual (dBm)	Act. Vs Est.	Est Pree Space minus PCC Est.
	Equip. Correc. (dB)		₹.							•	
1	Gas Mtr - Panoramic	5.03	750	650	25	-105	-110.1	-68.1	-101	-32.9	-28 - 5
2	HandiCup Factory	3.02	30	-70	348	-110	-105.7	-63.7	-106	-42.3	-23.0
3	Randy's House	2.68	130	30	12	-105	-104.7	-62.7	-101	-38.3	-21.5
4	Marin General Hosp.	1.68	70	-30	24	too low	-100.6	-58.6			
5	Andersen Serv. Ctr	2.07	30	-70	310	· - 75	-102.4	-60.4	-71	-10.6	
6	San Quentin	3.07	60	-40	310	-110	-105.8	-63.8	-106	-42.2	-23.5
7	Ind. Light & Magic	1.66	30	-70	295	-75	-100.5	-58.5	-71	-12.5	-18.0
8	K-776 Cap Bank	3.81	30	-70	240	-110	-107.7	-65.7	-106	-40.3	-25.0
9	LR-418 Recloser	1.68	210	110	210	-90	-100.6	~58.6	-86	-27.4	
10	Light Pole-4th St	0.34	50	-50	118	-70	-86.7	-44.7	-66	-21.3	-5.0
11	Marin Academy	0.58	100	0	132	-87	-91.4	-49.4	-83	-33.6	-8.5
12	Sr.Francis Drake-hub	1.89	80	-20	104	-100	-101.6	-59.6	-96	-36.4	-18.0
13	San Anselmo Substa.	1.98	80	-20	106	-102	-102.0	-60.0	-98	-38.0	
14	76 Station at hub	1.98	80	-20	104	-106	-102.0	-60.0	-102	-42.0	
15	Gas 24A 5th & H	0.68	50	-50	110	-86	-92.8	-50.8	-82	-31.2	. -9. 0
16	217 Humboldt	1.38	90	-10	128	- 95	-98.9	-56.9	-91	-34.1	-16.5
17	Clark & San Rafael	0.68	50	-50	58	-77	-92.8	-50.8	-73	-22.2	-9.0
15	31 Hillview	1.02	50	-50	338	-78	-96.3	-54.3	-74	-19.7	-14.0
15	Dominican College	1.00	120	. 20	224	-82	-96.1	-54.1	-78	-23.9	-14.0
	Civic Center	1.75	130	30	178	too low	-101.0	-59.0			
21	Gas at 2nd & C St	0.24	50	-50	90	~58	-83.7	-41.7	-54	-12.3	-2.5
	Switch Yard	0.08	50	-50	0	-45	-74.2	-32.2	-41	-9.8	0

APPENDIX A

Microwave Line Of Sight



Freet 5.13 (a) Typical radiolisk terminal transmitter. (b) Typical radiolisk terminal sections.



Normal Link Equation

$$P_r = \frac{P_T G_T \cdot \eta A_R}{4 \pi D^2}; \qquad N_r = k T_R B; \qquad \frac{P_r}{N_r} \ge (\frac{C}{N}) \text{ required}$$

or: using
$$L_{fs} = 20log(\frac{\lambda}{4\pi b}); \eta A_R = \frac{G\lambda^2}{4\pi}$$

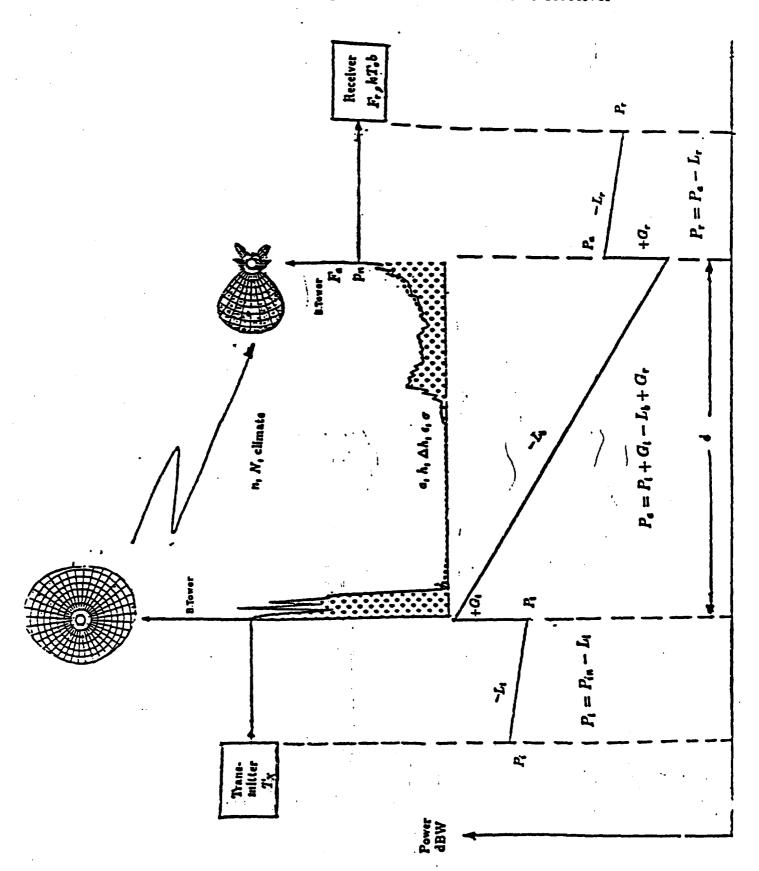
$$ERP = P_TG_T; \text{``C/kT''} = B \cdot (C/N)$$

$$\mathrm{ERP} + (G_R/T_R) + L_{fo} = (\mathrm{``C/kT"}) + \mathrm{k}$$

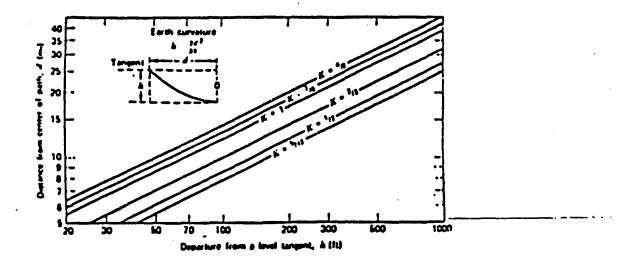
Must add attenuation and fading margin.

$$ERP + (G_R/T_R) + L_{fs} - Att - FM_s = ("C/kT") + k$$

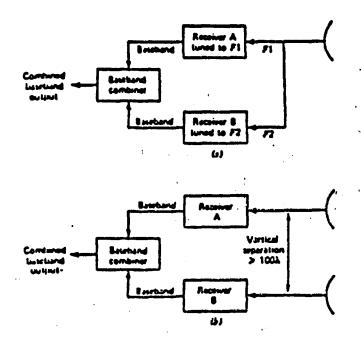
RF Power Flow Diagram From Transmitter to Receiver



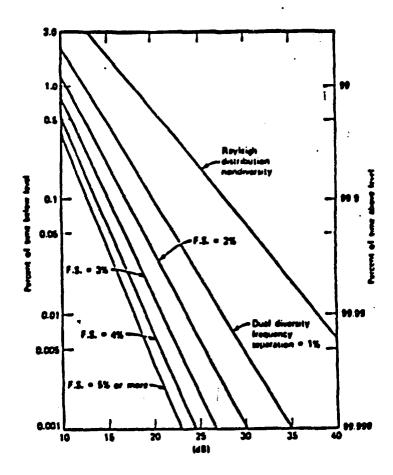
Earth Curvature or Earth Bulge for Various K Factors



- (a) Simplified Block Diagram of a Frequency Diversity Configuration
 - (b) Simplified Block Diagram of a Space Diversity Configuration



Approximate Interference Fading Distribution



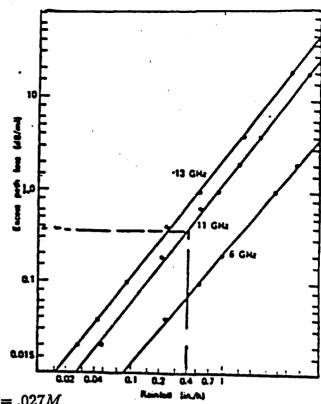
Approximate interference fading distribution for a nondiversity system with Rayleigh fading versus frequency diversity systems for various percentages of frequency separation (F.S.). (Note: Signal level referred to unfaded level for radiolinks; signal level referred to median for tropospheric scatter.

Single-Hop Propagation Reliability (%)	Fade Margin (dB)
90	8
99	18
99.9	28
99.99	38
99.999	48

Example:

Send an FM television signal through a microwave relay

- 25 miles separation
- 4' antenna transmit and receive.
- 11 GHz frequency
- Rain margin for 0.4 (inch/hr) rain fall
- Fading margin for 99.9 percent reliability
- $T_R = 500$ ° $K \rightarrow 27$ dB



$$L_{fs} = 20log\left(\frac{.027}{4\pi \times 2.5 \times 1.609}\right) = -145[dB], \lambda = .027M$$

$$G_t = G_R = \frac{4\pi R_R}{(\lambda^2)} \eta = \left(\frac{\pi d}{\lambda}\right)^2 \eta = \left(\frac{\pi \cdot 4t \cdot .3048}{.027}\right)^2 .55 \rightarrow \underline{40.4[dB]}$$

Excess poth loss due to minfall

From earlier examples on television for relay:

FM carrier with C/N of 12 dB, B of 36 MHz gives 52 dB S/N.

.. "C/kT" =
$$12 + 75.5 = 87.6 [dB \cdot dBHz]$$

- For 99.9 percent reliability fading margin = 28 dB = FM.
- For rain 0.4 in/hr @ 11 GHz attenuation is .3 dB/mi.

in 25 Mi the attenuation is 7.5 dB = Att.

$$ERP = -(G_R - T_R) - L_{fs} + Att + FM + "C/kT" + k$$

$$ERP = -(40.4 - 27) + 145 + 7.5 + 28 + 87.6 - 228.6 = 26.1 dBW$$

$$RP = ERP - G_T = 26.1 - 40.4 = -14.3 \text{ dBW} \rightarrow 37 \text{ milliwatts}$$

How much power is needed at 6 GHz?

$$\lambda = 0.05M$$

• $G_T = G_R = \left(\frac{\pi \times 4 \times .3048}{.05}\right)^2.55 \rightarrow 35 \text{ dB}.$

(40.4 @ 11 GHz)

- $L_{fs} = 20 \log \left(\frac{.05}{4\pi \times 25 \times 1609} \right) = -140 \text{ dB.}$ (-145 @ 11 GHz)
- Attenuation is .09 dB/mi; Att = 2.25 dB.

(7.5 @ 11 GHz)

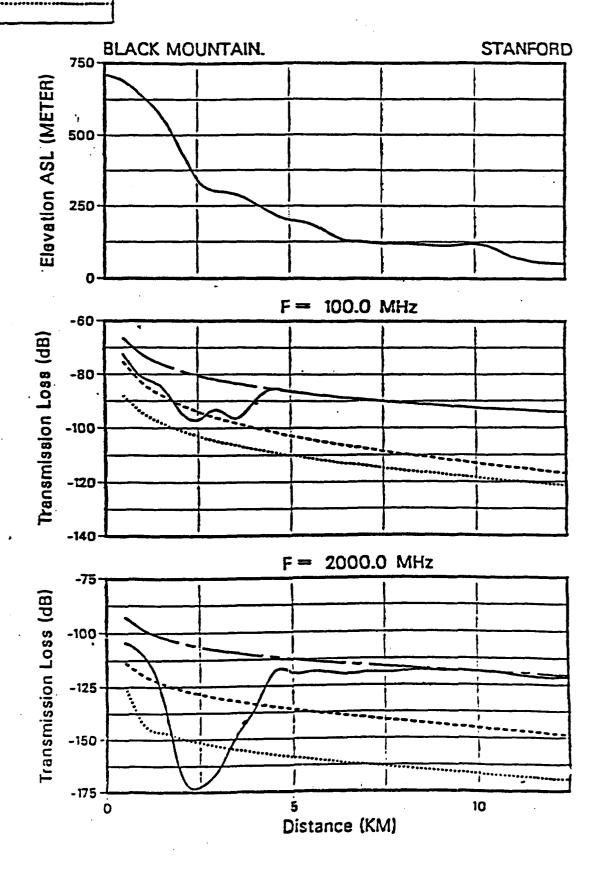
$$ERP = -(35 - 27) + 140 + 2.25 + 28 + 87.6 - 228.6 = 21.25 dB$$

$$RP = 21.25 - 35 = -13.75 \rightarrow 42/\text{milliwatts}.$$

LEGEND
FREE SPACE LOSS
DETAILED L-R
AREA MODE L-R
CCIR CURVE

しまり

Propagation Predictions



Field Strength vs. Distance

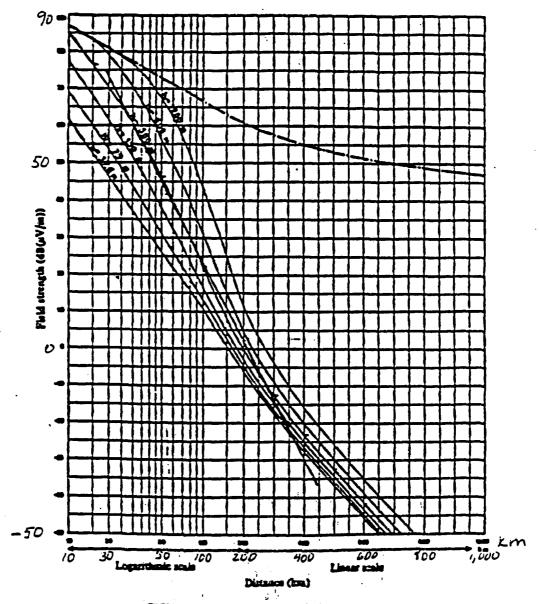


FIGURE 9 — Field strength ($dB(\mu V/m)$) for 1 kW e.g. Frequency: 450 to 1000 MHz (Bands IV and V); Land; 50 % of the time; 50 % of the locations; $h_0=10$ m; $\Delta h=50$ m

Free inter

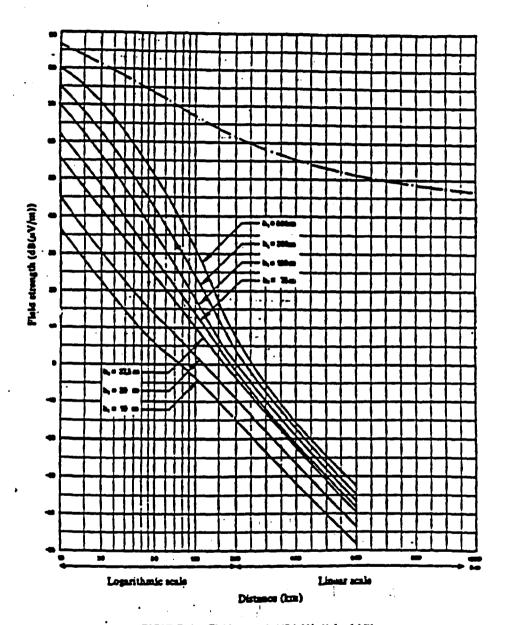


FIGURE 4 - Field strength (dB(uV/m)) for 1 kW exp.

quency = 150 MHz, land, rural 50 % of the time; 50 % of the

locations; k, = 3 m

Units of Signal Strength

1. Power Density $W = Watts/M^2$

Field Strength E = Volts/M

Power Flow is E×H; in free space E⊥ H and $|H| = \frac{|E|}{120\pi} = \frac{|E|}{3776}$

Therefore:

$$W = \frac{E^2}{120\pi}; \qquad E = \sqrt{120\pi \cdot W}$$

2. Field Strength expressed as dBu. dBu means dB relative to 1 μ volt/M = 10⁻⁶ volts/M. Power Density for 1 μ Volt/M field Strength:

$$W_{\mu\nu}/M = \frac{(10^{-6})^2}{120\pi} = -145.76 \ dbW/M^2$$

$$0 dBu = -145.76 dBw/M^2$$

3. Express in terms of transmitter with P_t watts at a distance, d, with unity gain antenna.

$$W = \frac{P_t}{4\pi d^2}$$

$$E = \sqrt{\frac{120\pi P_t}{4\pi d^2}}; \quad E = \frac{\sqrt{30 P_t}}{d}$$